Advanced Science Processing and Visualization

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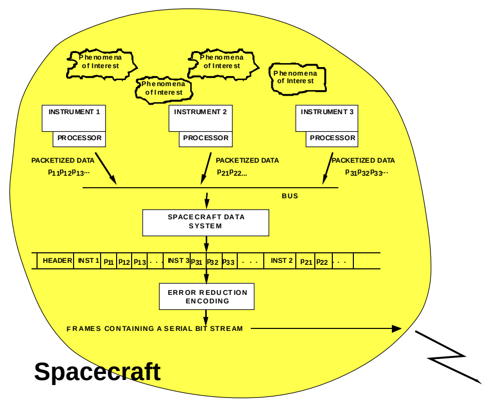
Objective and Significance

Provide science and operations technologies to support the complete science instrument lifecycle …

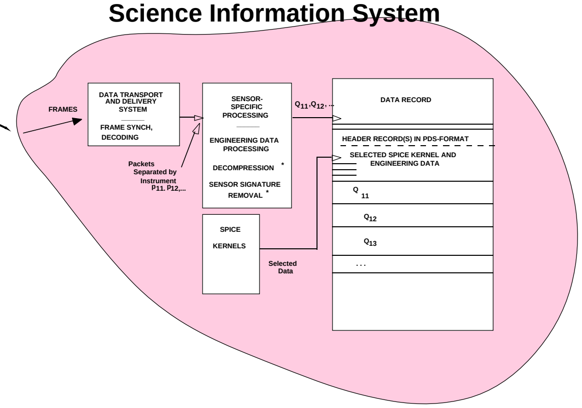
- **-- from instrument concept (e.g., gse, flight software, payload interface, flight science processing)**
- **-- through operational science (e.g., planning, instrument health, data display, analysis, visualization, archival data record production and photoprocessing)**

for all science instruments on all flight projects.

- **Science planning**
- **Instrument health and safety**
- **Data display (stereo)**
- **Data Analysis**
- **Data visualization (stereo)**
- **Archive**
- **Photo processing**
- **Instrument calibration/decalibration**
- **Compression/Decompression**



Science Information System



- **Flight software**
- **Payload interface**
- **Flight Science processing**
- **Instrument calibration/decalibration**
- **Compression/Decompression**

Fundamental Problem Facing Us

Problem: how to provide long range surface mobility and science acquisition by mobile instruments, aerovehicles for global atmospheric exploration, and miniature mobile devices and sensor systems for subsurface exploration. Surface, subsurface and in-atmosphere operations are quite different than operations for cruise, flybys or orbits. The in-situ environments are unknown, variable, and hostile. Small, power-limited surface missions such as metrology networks, aerobots, penetrators, etc., will require surface/orbital relay of communications, such as a surface rover which uses a balloon for overhead imagery and communication.

The information processing systems that are needed to support these types of missions ARE really vastly distributed systems with large temporal delays - the problem becomes on of how to provide a infrastructure that takes into account the temporal and spatial aspects of these missions - there will be data management problems on Mars with these missions types.

Long range, lightweight, survivable rovers

Multisensor based surface navigation

Penetrators, subsurface explorers

Hybrid mechanisms capable of flying/roving

Autonomous instrument and spacecraft operations technologies

- **Autonomous navigation, instrument pointing, instrument sequence design, information extraction and communication.**
  - **feature recognition/ morphological recognition**
  - **feature tracking/ morphology tracking**
  - **mosaicking**
  - **information extraction**
  - **adaptive data compression algorithms.**

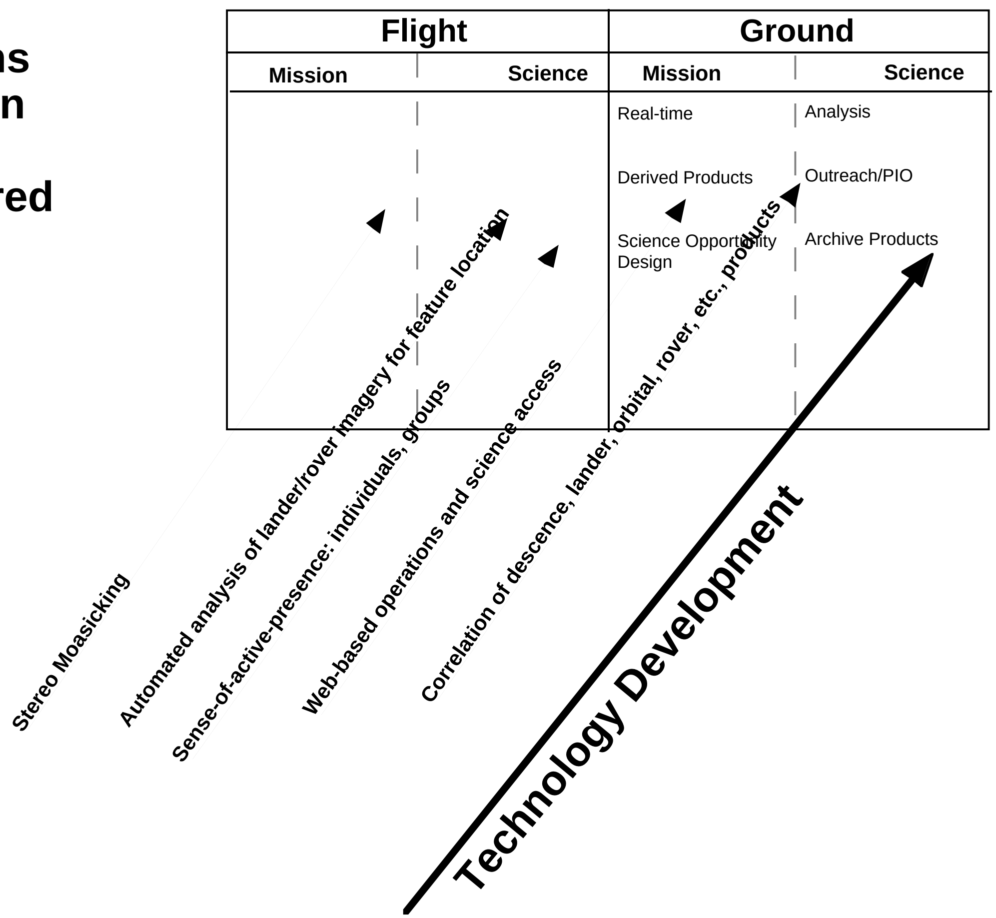
  or autonomous change/phenomena recognition with autonomous stereo mosaicking; adaptive progressive compression on spatial/spectral dimensions constrained by quality, quantity, local store, bandwidth, ...
- **Higher level data product support for operations & science analysis**
  - **Automated mosaicking based on sensor model (orbiters, landers & rovers, and arms)**
  - **Mosaics, quicklook/working hardcopy and large format prints, and derived products**
  - **Multisenor product fusion**
- **Digital Elevation Model (DEM) derivation--stereo. clinometry, ...**
- **Perform map projections on irregular planets like asteroids and comet nuclei**
- **Tools and technologies for assisting, and automating, locating landers and rovers. etc. on planetary/cometary/asteroidary surfaces.**
- **Navigation of multi-resolution, multi-sensor, stereo data sets for operations and science.**

  Tools and technologies for advanced telemetry visualization through the use of higher-level graphics linked to telemetry parameters

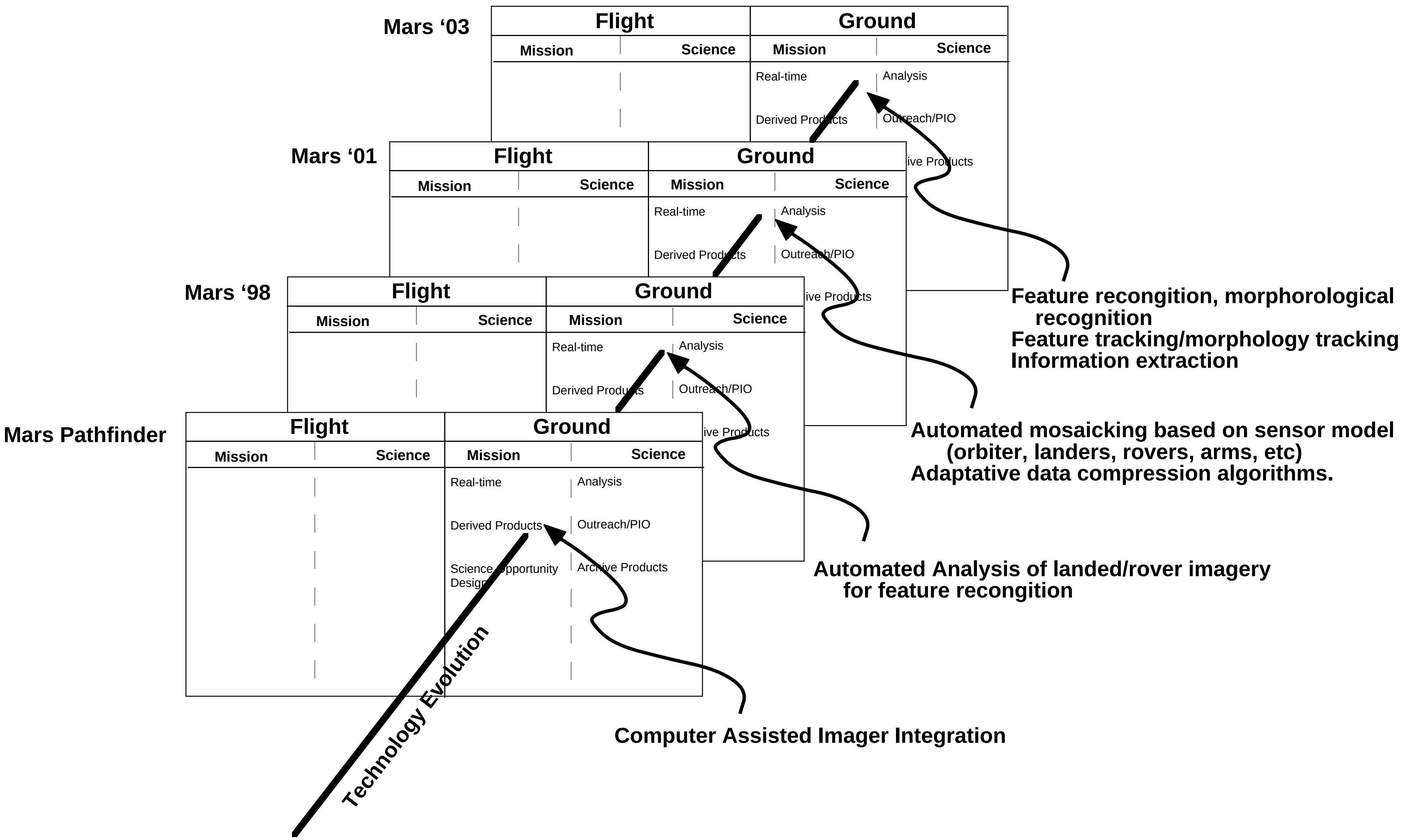
Autonomous instrument and spacecraft operations technologies (continued)

- Rover/sensor/arm/etc. mission planning and data analysis tools; give the operator a "sense of presence" in the rover's/sensor's environment. This system will give the user the sense of being immersed in the environment the rover/etc. is investigating with the freedom to examine scientific data without being bound to the point-of-view of the rover; determine the modalities are more effective for different types of tasks. An additional mode is a view on a "Virtual Workbench" type of display providing a high-resolution, stereo display of a terrain region in a map-like layout intuitive to route planners. A third mode of free-flight through the region using stereo displays is also effective for some types of tasks
- (autonomous) Robotic arm mission planning tools; based on scene visualization with sample point designation, operations rehearsal and simulation, and Inverse Kinematics (IK) with system operational constraints
- Ability to display and process stereo data allows for faster recognition of geological or atmospheric formations, identification of perilous obstacles for rover navigation, and is a starting point for generating a data representation for targets that are viewed from multiple observation points, such as from a lander and rover; camera pointing correction based on image correlation, stereo mosaic generation of stereo imagery, and determination of camera orientation based on range-finding.
- Data distribution/access to information -- WEB-centric Interface for databases; provide easy access to organized databases of planetary & Earth images, maps, text, and animations
- Change and feature tracking -- establish an operational displacement measurement, velocity measurement, atmospheric analysis and atmospheric animation capability
- WEB-centric operations for distributed science and operations teams Distributed Internet-based command generation; and 2) 3D visualization over the Internet.
- Neural net data mining --develop new methodologies for advanced analysis of time-varying scientific data.
- To analyze the imagery on the spacecraft and to extract features of interest rather than returning all the data with a uniform level of compression damage
- Algorithms to maximize the science value of data returned from spacecraft instruments.

There are two dimensions to SIS MIPL/DIAL/SSV support to JP{L missions. Essentially, they are flight and ground support with sub-aspects of Mission Operations Support and Science Operations Support. The third dimension in the figure represents the technology/development required to provide the services.



Evolving Technology Needs and Development



Advanced Science Processing and Visualization

Reference -- Technology, Development, and Coordination Tasks

Title	Short Description
SCIENCE/OPERATIONS COORDINATION	Review science proposals accepted for funding by NASA. Establish operational requirements on payload instruments. Develop plans for operational support if not included in AO response. Establish interface between operational GDS and science payload instruments. Plan and conduct operational tests.
AUGMENTED MARS 98 OPERATIONS, SCIENCE & PIO SUPPORT	Will provide Pathfinder level product set for Mars 98 MVACS payload--mosaics, web based science data base, animations and data visualization products, custom enhanced products, large format prints, press release products in all required formats, etc
AUGMENTED MARS '01 OPERATIONS, SCIENCE & PIO SUPPORT 388/345	TBD
TECHNOLOGY FOR ROVER IN SITU AUTONOMOUS LOCATION 388/345	Automated analysis of lander/rover imagery for feature location Correlation with landmarks in descent imagery, and image data bases from prior missions and MGS to triangulate lander/rover positions
3D WEB INTERFACE FOR TELESCIENCE (WITS) 345	Extend existing WITS capability to support flight operations. Integrate with SEQGEN and APGEN multimission software. Extend to multiple cameras, stereo views, and add solid model simulation.
STEREO MOSAICKING	Produce software to automatically mosaic images from stereo imagers, based on pointing information and image content. Utilize lessons learned from Mars Pathfinder to produce a multimission capability. Software will accommodate a variety of camera models and operate on images from landers, rovers and orbiters
VIRTUAL-REALITY MULTIMISSION ATLAS USER INTERFACE (VR-MAUI)	Provide desktop access to planetary image data bases to a geographically distributed science community with an intuitive interface in order to support landing site selection for future missions, and science and operations analysis during flight operations. Extends prototype used on Mars Pathfinder.
PLANETARY IMAGE ATLAS IMPROVEMENTS	Extends web-based image data management tools developed by PDS to support flight operations environment. Produces web-based browse capability with appropriate security controls for use in flight operations.
SENSE-OF-PRESENCE SUPPORT OF OPERATIONS AND SCIENCE ANALYSIS	Provides facility enabling viewing of active mission data in 3D HDTV format by 30-40 people at a time

Objective and Significance

Goal	Significance
• Support new instruments and their associated science.	• For Interferometers: Develop a prototype operational system to : collect, archive, retrieve, analyze, visualize, and display science and engineering data from spaceborne optical and infrared interferometers.
• Algorithms to maximize the science value of data returned from spacecraft instruments.	• Develop image restoration techniques with respect transport, compression, etc., artifacts by utilizing total variation and wavelet algorithms
• Utilize data visualization technology to provide a multidimensional “sense of active presence” for operation and data analysis of teleoperated and semi-autonomous vehicles. • Provide a more intuitive and richer human/computer interface • Adapt maturing commercial technologies to the flight system environment.	• Extend reusable software libraries to interface with head-mounted display and motion tracker currently in laboratory • Evaluate state-of-the-art immersive environment technologies for applicability (Flostation, Cave, etc.) • Develop an immersive environment for scientific data analysis • Enhance environment to support vehicle control • Support integration into existing planning and operations tools Implement device-independent color

Objective and Significance (continued)

Goal	Signficance
• Improve display/presentation technology	• The infusion of digital stereo HDTV technology into all components of mission planning and operations
• Solve the map projection, display and visualization problem including on the users' desktop computer. Infuse client-based technology into mission operations and provide better access to science and instrument data.	• To provide easy access to organized database of planetary and Earth images, maps, topography, text, and animations. • To provide a platform-independent solution to this problem • To provide dedicated servers with complete copies of planetary data. • To create accurate map projections of irregularly shaped objects - asteroids, comets, and planetesimals
• Develop advanced visualization tools for spacecraft and rover telemetry to enhance understanding and usability	• Deliver DIAL animation tools and techniques which have proven useful to planetary science missions.
• Advanced in-situ services and tools	• Develop advanced 3D terrain modeling tools for use in robotic and rover operations planning and scientific data analysis

Products and Customers

Show any changes to this in RED.

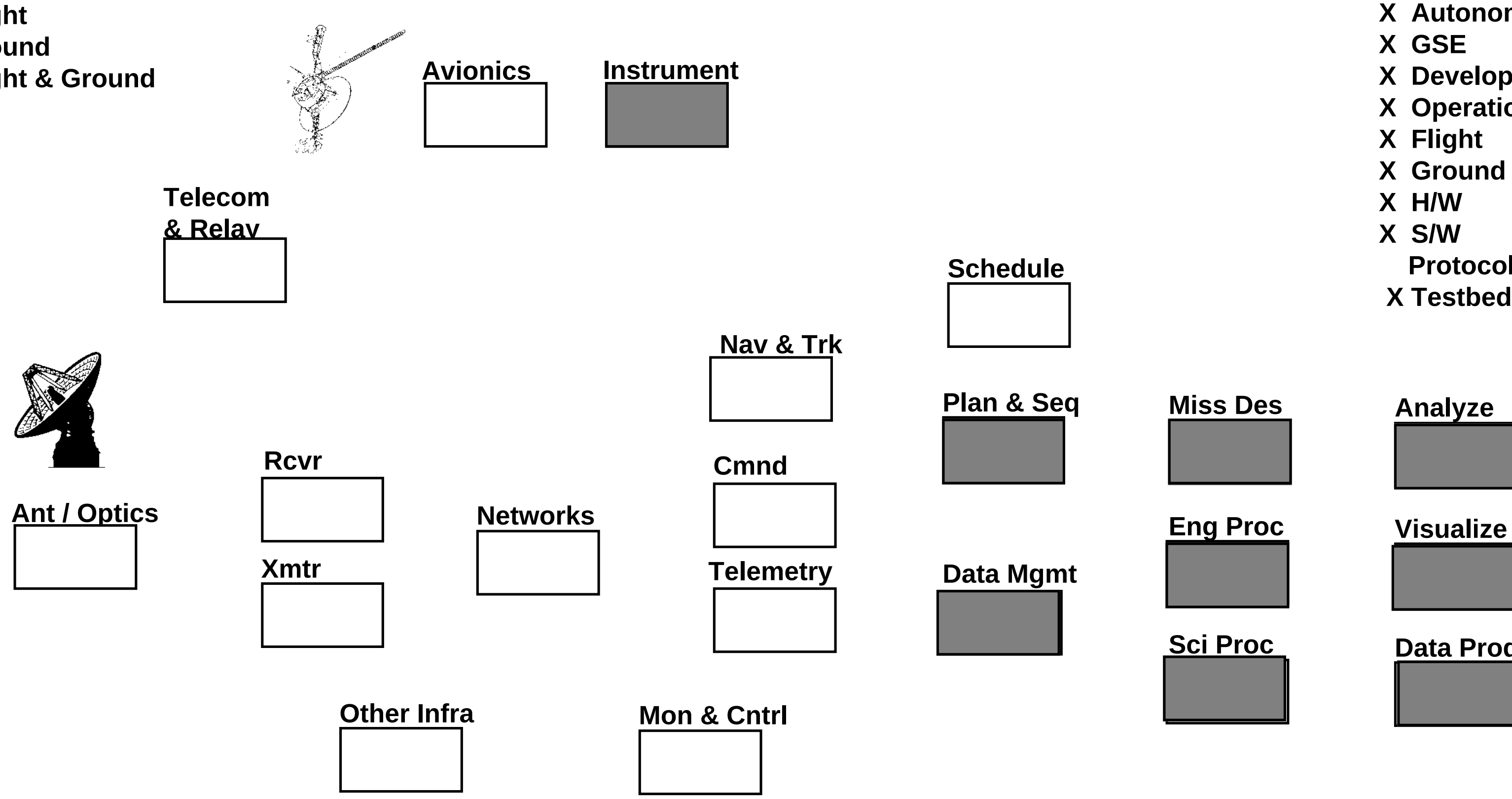
Product	*User/Customer*	*Development Phase* Concept	Design	Demo	Transfer	*Approach/Comments*
		■				

Advanced Science Processing and Visualization

The “Big” Picture

By filling boxes (using codes below), show graphically how your work area/unit fits into this high level view of the overall TMOD environment, name the elements of the end to end system you are working on and what layers in these functions you contribute to.

Fill Codes:
- Flight
- Ground
- Flight & Ground



Check all that apply:
- X Automation
- X Autonomy
- X GSE
- X Development
- X Operations
- X Flight
- X Ground
- X H/W
- X S/W
- Protocol
- X Testbed

Relevant Technical Skills

An integral part of the entire instrument and science life-cycle …

- –instrument development (GSE, calibration, instrument models, …)
- –science mission planning/design/development (ops scenarios, end-to-end simulation, testbed, compression/decompression, flight software, FST/SMOCC)
- –science ops (OPNAV, health and safety, real-time telemetry, instrument analysis, and systematic, science, archive products)
- –maintain/evolve system based on changing mission, instrument and science requirements, e.g., Galileo Phase 2.
- – post mission (archive)

While using a lifecycle approach to system development we provide:

- –rapid-prototyping or do-a-little/test-a-little methodologies
- –building upon baseline capabilities to yield an enhanced system … a rolling development.
- –MIPL/MPSF takes what is at hand as the starting point and evolves the capabilities.

With an integrated team of people who perform technology definition/implementation and design, development, cm, test, maintenance, science analysis, database management, archive. This team works closely together to support its customers, the scientist and instrument teams as early as the project proposal phase to the final, end-to-end instrument/ mission data system.

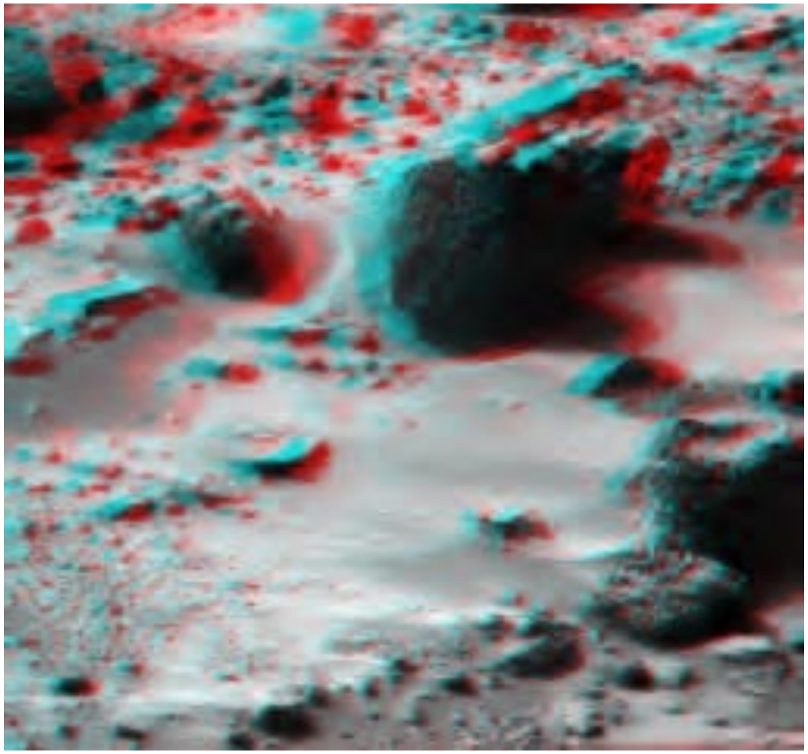
- **Data Compression - Dr. Arron Kiely**
- **Interferomteric Sensor Measuring and Modeling Environment (ISMME) - Dr Raymond Bambery, Dr. Eric De Jong**
- **Robotic Arm Mission Planning System (RAMPS) - John Wright, Richard Volpe**
- **Advanced Telemetry Visualization(ATV) - John Wright, Jack Morrison, Dr. David Paige- UCLA**

- **Adaptive Image Noise Reduction and Restoration - Gary Yagi, Dr. Justin Maki.**
- **Map Projection on Irregular Bodes - Jean Lorre, Dr. Yang Cheng- ORNL, Dr. Philip Stooke- University of Western Ontario**
- **Sense of Active Presence (SOAP) - John Wright, Frank Hartman**
- **HDTV - Visualization and Analysis Testbed - Dr. Eric De Jong, Shigeru Suzuki, Dr. Raymond Bambery**
- **Multimission Application JAVA Interface Clients (MAJIC) - Vadim Parizher**
- **Stereo Display Toolkit - Bob Deen**

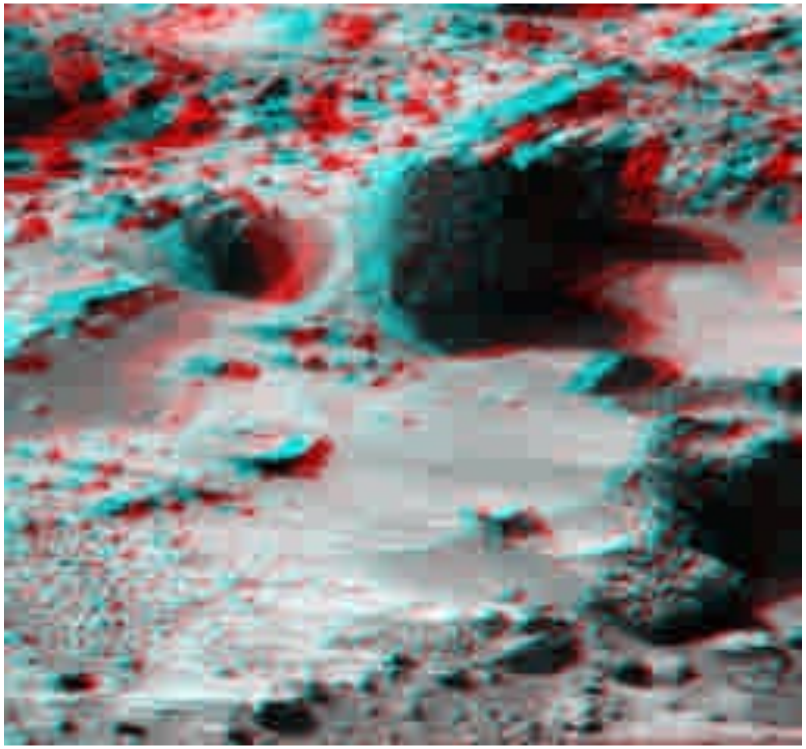
Data Compression

- **Quarter 1**
  - **accomplishments planned**
    - **Implemented and tested lossless compression algorithm in verilog hardware description language. Synthesized to Actel FPGA architecture.** **(Significance: hardware implementation of a state-of-the-art lossless image compression algorithm.)**
    - **Developed software for fast and efficient compression of NEAT sky survey images.** **(Significance: new software is more than five times faster than commercial software previously used, and offers lower distortion at the same compression level.)**
    - **Performed simulations and analysis for error containment strategies in compressed data.** **(Significance: error containment strategies limit the propagation of errors in compressed data)**
    - **Begun investigation of distortion-controlled compression. Included a crude version for NEAT software.** **(Significance: distortion-controlled compression allows data compression with a user-selectable local distortion guarantee.)**
    - **Planned architecture for web-accessible compression testbed. Selected several test images.** **(Significance: a web-accessible testbed allows scientists to determine the effects of compression on sample data.)**
  - **additional accomplishments**
    - **Tested two lossy compression methods on new sample data for MIRO (Rosetta instrument).**
    - **Provided compressed stereo images for Mars 2001 study**
- **Quarter 2 - planned accomplishments**
  - **Synthesize VHDL algorithm to Xilinx XC6200 architecture**
  - **Web-accessible compression testbed operational**
- **Quarter 3/4 - planned accomplishments**
  - **demonstrate FPGA hardware image compression prototype**
  - **report on error containment strategies in compressed data**
  - **report on distortion-controlled compression**

Stereo Image Compression for Mars 2001 Study



wavelet-based progressive method



JPEG non-progressive method

- **Each image compressed to 1.2 bits/pixel (.6 bits/pixel for each eye)**

Interferometric Sensor Measuring and Modeling Environment

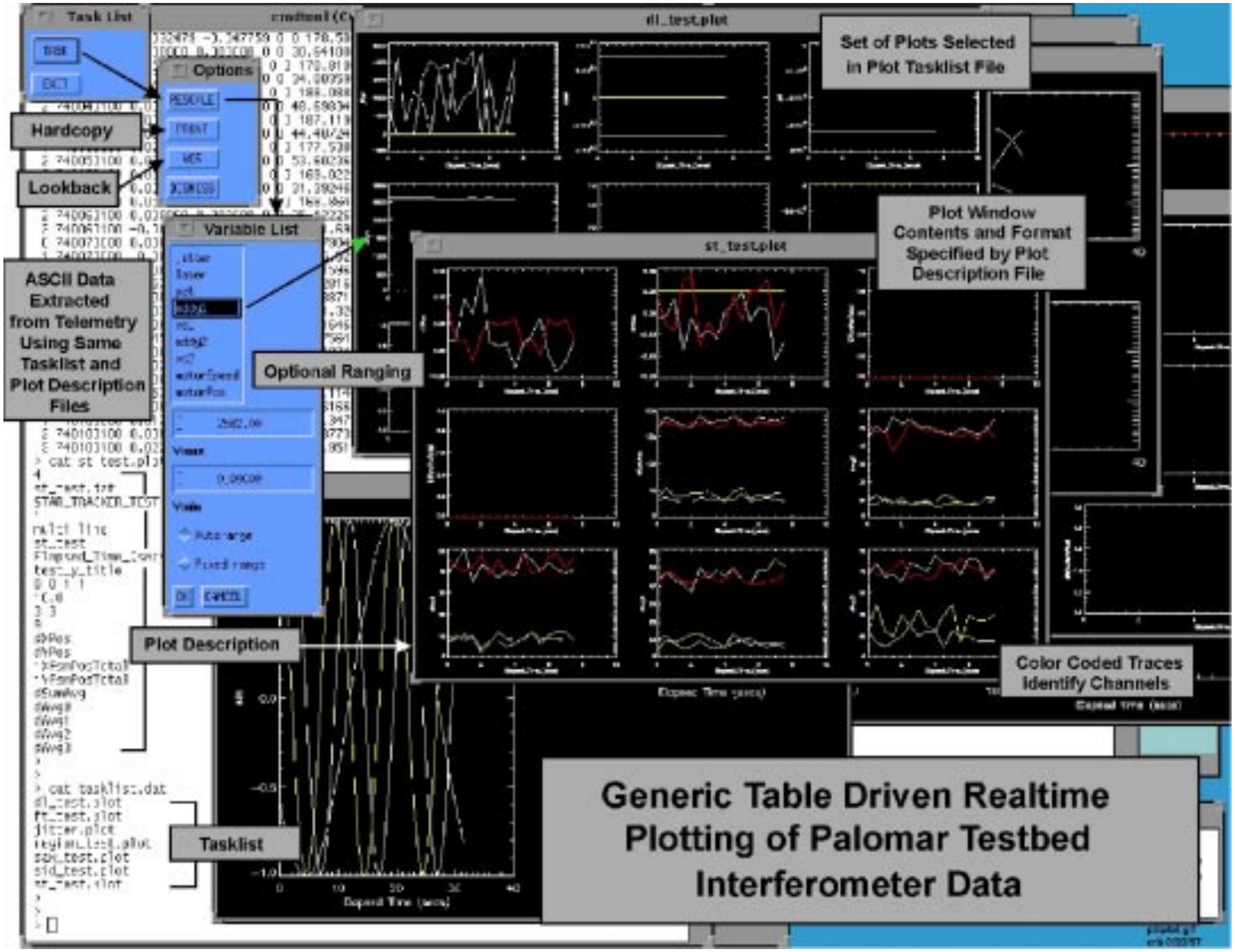
- **Current focus**
  - **Development of Science Analysis Processing functions based on Space Interferometery Mission (SIM) science requirements and mission design. SIM chosen as the flight mission due to**
    - **Advanced state of mission design, and**
    - **Support of an active science working group**
  - **Development of Instrument Analysis Processing functions based on the Palomar Testbed Interferometer (PTI). PTI chosen as an instrument prototype due to**
    - **Similarity to the SIM design, and**
    - **Active science program - Xiao Pei Pan and C. D. Koresko - PIs at Caltech**

FY98 Q1 Accomplishments and Follow-On Work

Interferometric Sensor Measuring and Modeling Environment (ISSME)

- **Quarter 1**
  - Presented summary of SIM GDS design to NASA Headquarters personnel and Origins Program Office.
  - Palomar Testbed Interferometer (PTI) - integration of first prototype Real-Time Graphics Display into PTI operations.
  - Completed SIM requirements evaluation.
  - Palomar Testbed - plotted acquired data in real-time on PTI hardware.
  - Completed prototype SIM data products descriptions.
  - Palomar Testbed - plotted acquired data in real-time on PTI hardware.
- **Quarter 2**
  - Complete data display interface for PTI
  - Incorporate PTI data analysis tools into Science Visualization Testbed (SVT)
  - Evaluate tools being used on SIM and PTI testbeds for inclusion into SIM ground system design
  - Design prototype generic interferometer telemetry stream based on PTI data
- **Quarter 3/4**
  - Undertake evaluation of data analysis requirements for New Millennium Program DS3 Mission
  - Evaluate SIM end-to-end testbed, STB-3, data analysis requirements
  - Evaluate use of SPICE kernels in interferometry missions

Interferometric Sensor Measuring and Modeling Environment (ISSME)



Robotic Arm Mission Planning System (RAMPS)

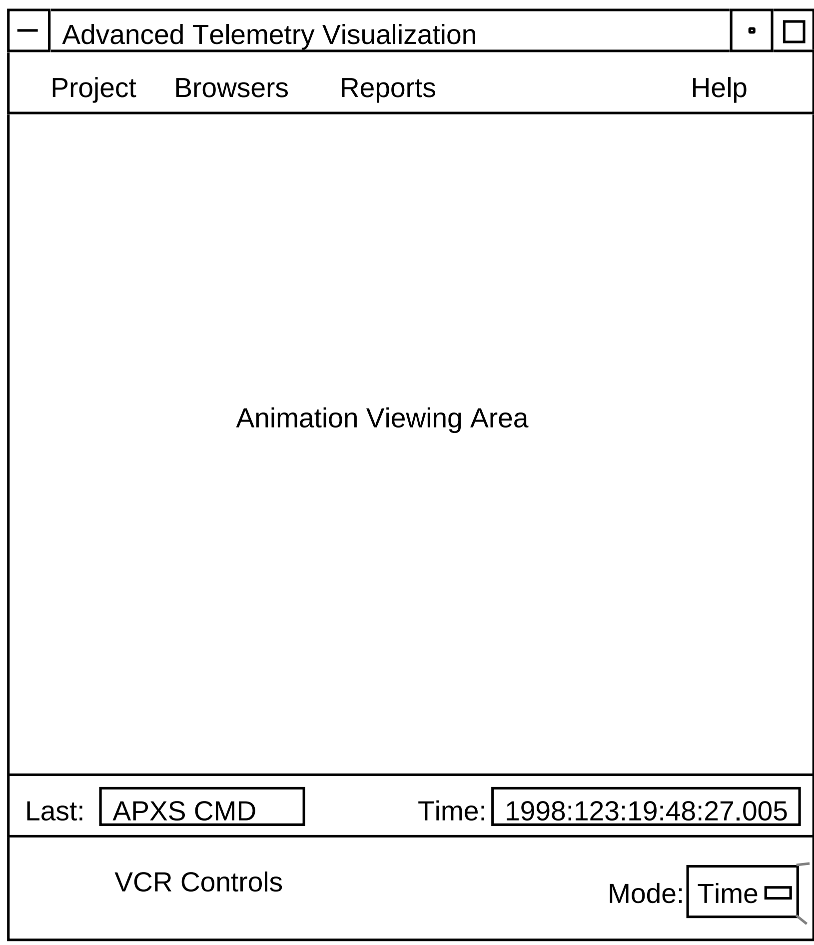
- **First Quarter Accomplishments**
  - **Developed advanced terrain visualization tool**
  - **Developed preliminary system block diagrams for creation of 3D terrain models from various sources of imagery**
  - **Collaborated with robotics group of section 345 to develop VRML models and tools for 3D WITS for science mission support**
- **Second Quarter Plans**
  - **Collaborate with robotics and MIPL to refine system block diagram**
  - **Collaborate with MVACS team to define model output format for use during Mars '98 mission**
  - **Begin development of system modules**
- **Remaining First Year Plans**
  - **Continue development of system modules**
  - **Integrate with MVACS Telegrip system for mission operations**

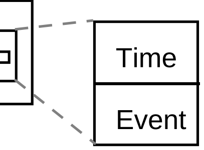
FY98 Q1 Accomplishments and Follow-On Plans

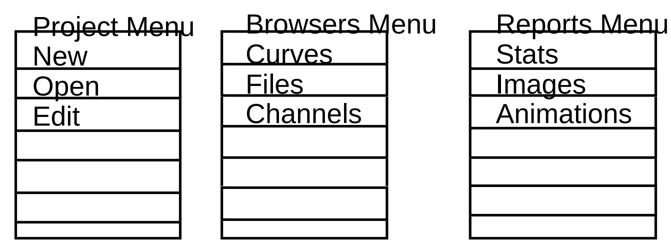
Advanced Telemetry Visualization (ATV)

- **First Quarter Accomplishments**
  - **Developed preliminary telemetry description language spec**
  - **Developed simple tool for visualizing Sojourner telemetry**
  - **Demonstrated visualization of actual Sojourner kinematic telemetry**
  - **Designed graphical user interface for visualization tool**
- **Second Quarter Plans**
  - **Begin software development of user interface**
  - **Deliver finalized language and model specs to MVACS team**
- **Remaining First Year Plans**
  - **Develop user interface**
  - **Integrate with MVACS model and descriptions for mission operations**

Sample ATV Interface Layout





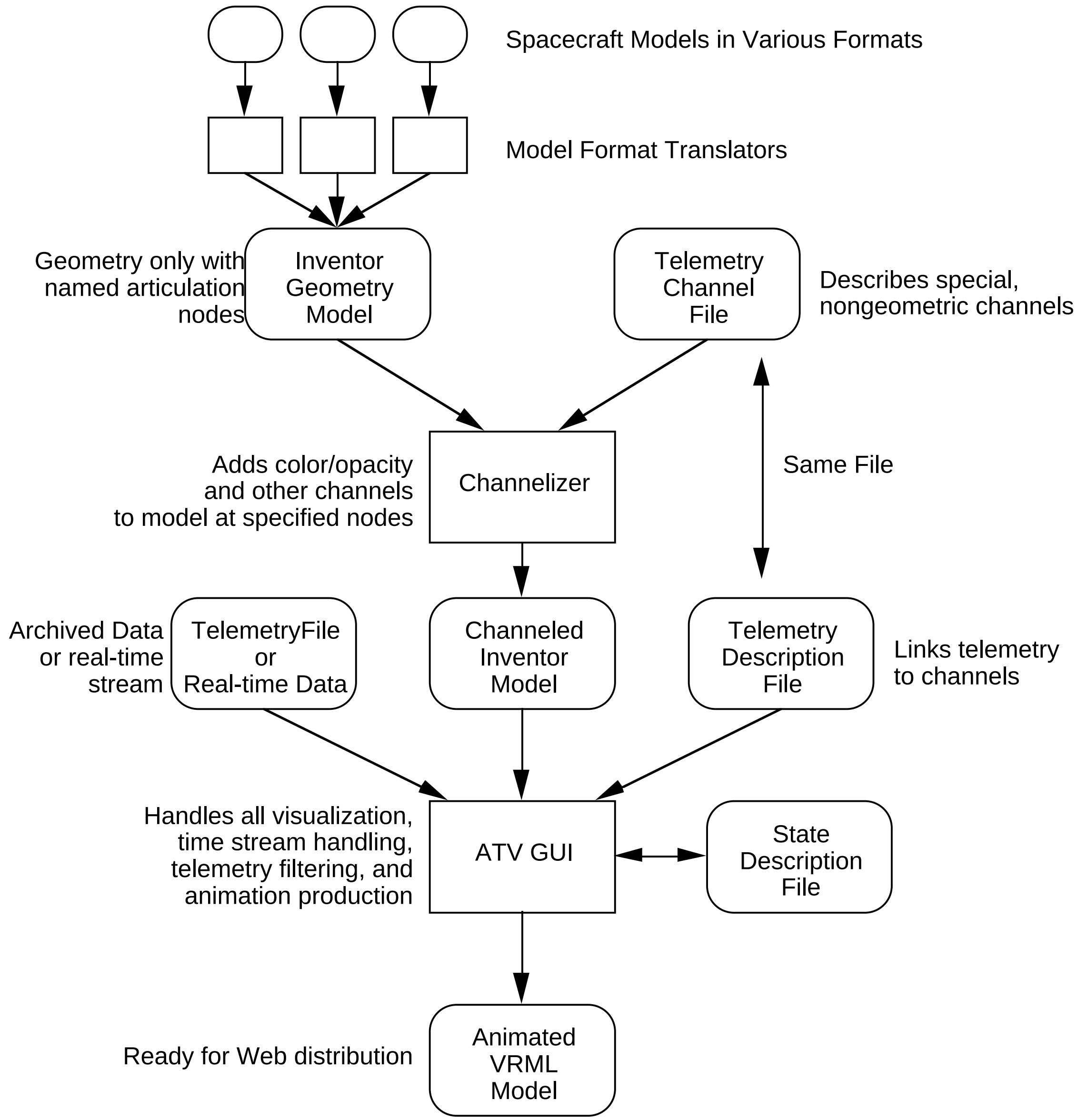


Time Range Chooser Tool??
Telemetry File Browser??
Current Project Display??

Current Project Data Window

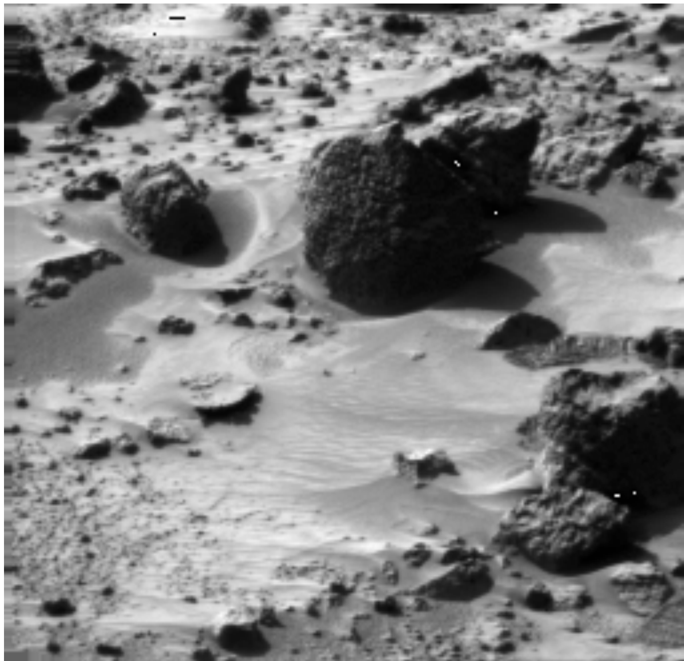
Path Editor Curve Tool

Advanced Telemetry Visualization (ATV)

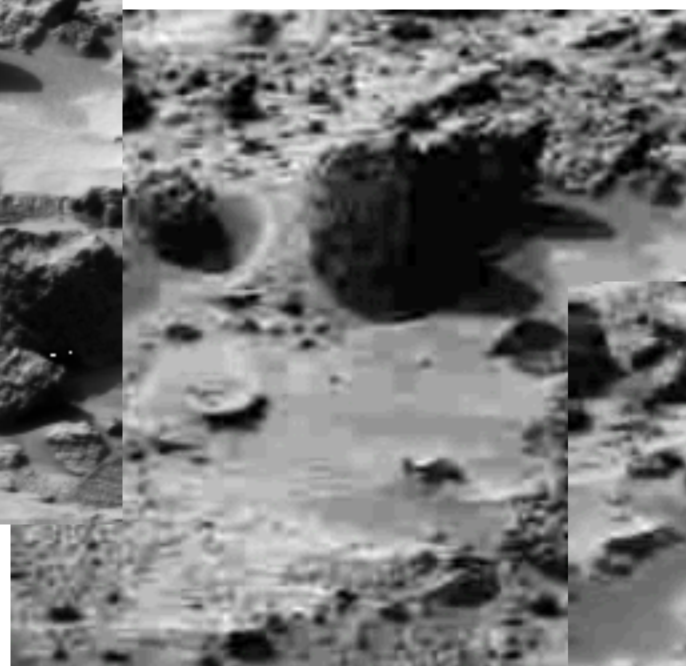


Adaptive Image Noise Reduction and Restoration

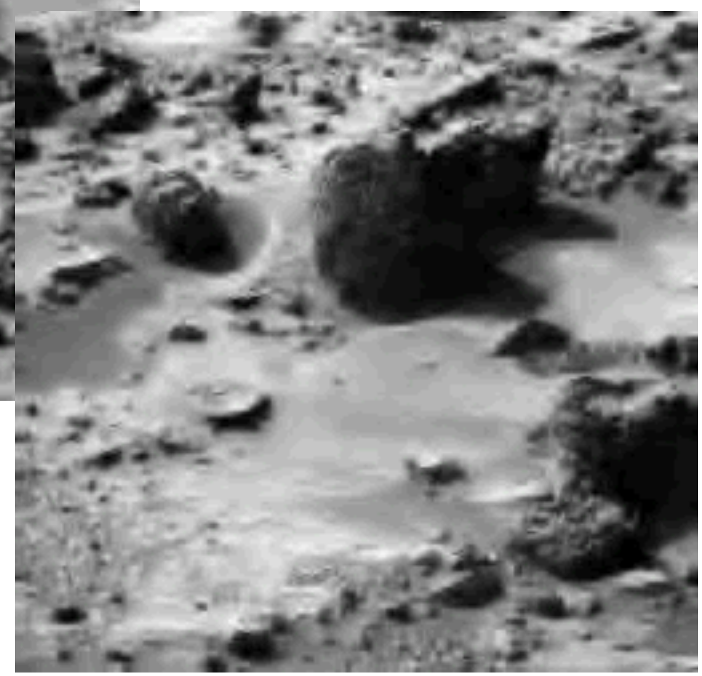
- **Quarter 1**
  - **Prototype VICAR-based program for basis of Adaptive Total Variation (ATV).**
  - **Initiated characterizing image compression artifacts. In particular, examining the difference between JPEG and Wavelet artifacts (this is related to the compressor system design for the 2001 Mars Rover).**
    - **Three images are on the following vugraph. The first one, i1248280625l.img_0182010086, is an uncompressed image. The second one, B44_jpeg, is a JPEG compressed image (0.44 bits/pixel). The third one, BL3B44, is a wavelet compressed image (0.44 bits/pixel). The compression artifacts between the two compressed images are radically different. The JPEG image contains the typical blocky artifacts, while the wavelet image shows no blockiness but appears "blurry". The JPEG blockiness occurs because the quantization error in the JPEG image is disproportionally "bunching" up on the edges of the 8x8 blocks, while the wavelet algorithm tends to distribute the errors more even throughout the image.**
- **Quarter 2**
  - **Complete the analysis of Mars '01 compression problem. Select an approach: use a smoothing function (in histogram space) and "blur" the spikes back down into the curve using the regularization algorithms on the histogram.**
  - **Prototype and test the algorithm.**



i1248280625l.img_0182010086



B44_jpeg



BL3B44

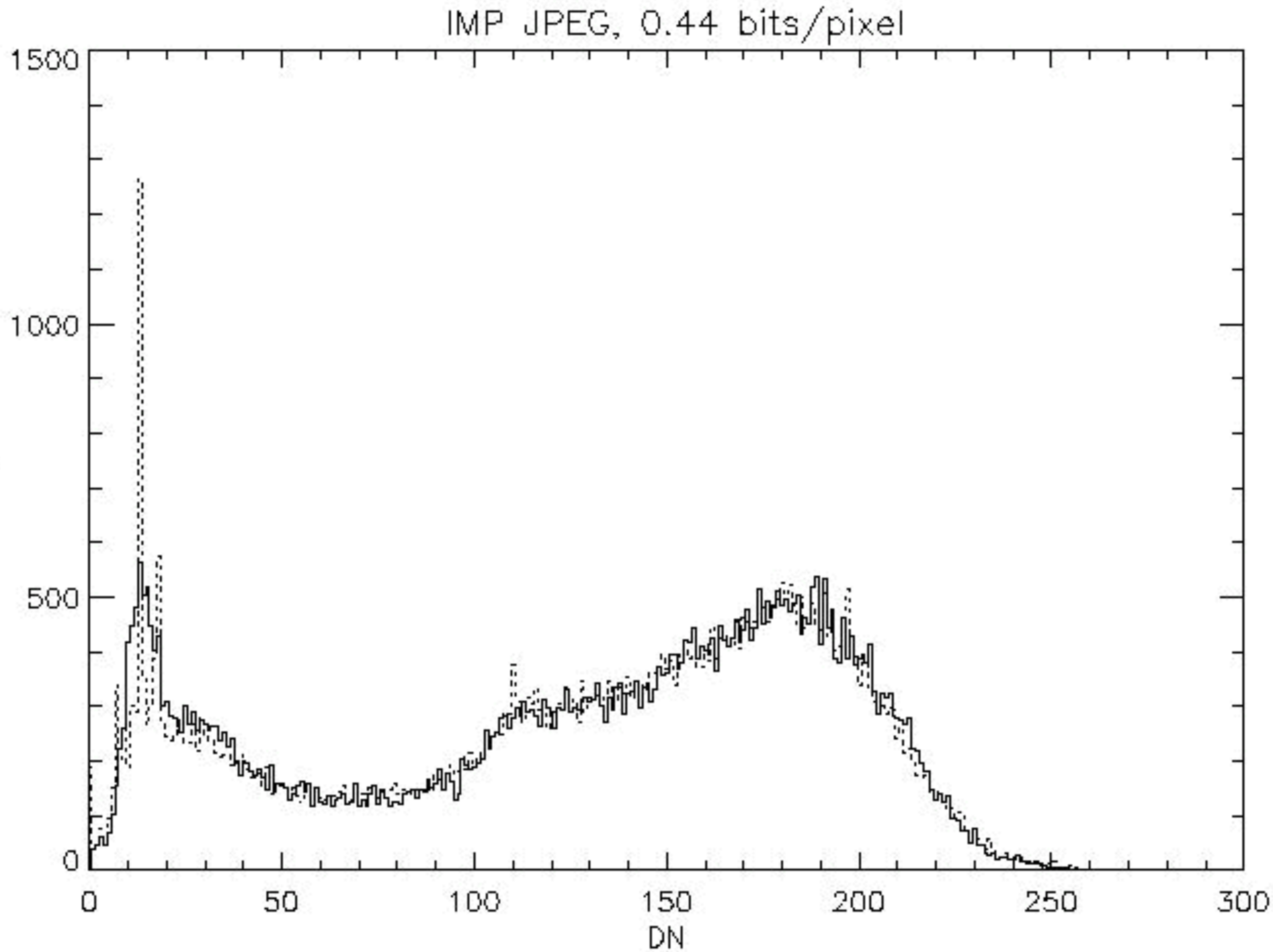
JPEG Vs Wavelet Compression

If one looks at the histogram of a JPEG compressed image, and compares it to the histogram of a raw image, you can see that the JPEG compressor [dotted line] adds "spikes" to the data (see jpeg_hist_440

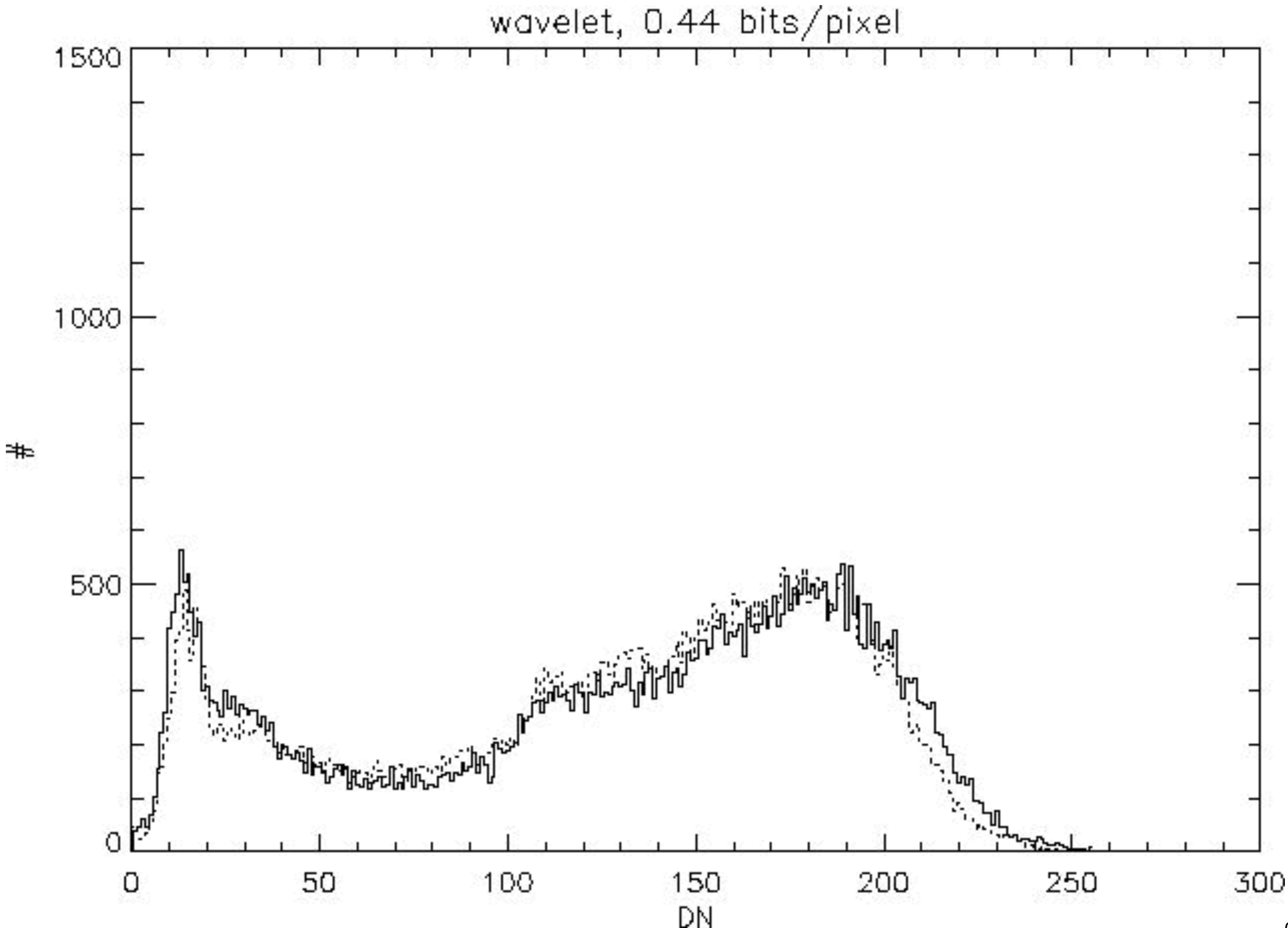
Note the number of pixels with DNs immediately to the left and right of the spikes are deficient relative to the original (solid line). This is simply the quantization effect (where all of the neighboring pixels [in DN space] are getting quantized to a single DN and forming a spike).

The wavelet algorithm doesn't exhibit this characteristic (see wavelet_hist_44)

jpeg_hist_44


IMP JPEG, 0.44 bits/pixel
1500
1000
500
0
0
50
100
150
200
250
300
DN

wavelet_hist_44



Map Projections on Irregular Bodies

- **Quarter 1.**
  - Dr Cheng's authalic solution code has been converted to VICAR and is presently being modified to conform to existing file conventions.
  - Achieved agreement between the numerical case (Approach 2) and the closed form solution for the triaxial ellipsoid (Approach 1) for both the authalic and conformal conditions. Map project Phobos in both authalic and conformal conditions.
  - Map projected an image of Phobos using Dr Cheng's authalic solution.
  - Find a conformal solution to the Cauchy equations (Approach 3).
- **Quarter 2.**
  - Convert Dr Cheng's conformal solution to vicar.
  - Map project Phobos conformally.
- **Quarter 3.**
  - Deliver all vicar programs in a form suitable for flight project use.
  - Assemble and deliver planet models for all objects of known shape in the solar system, in a format compatible with the above software.
  - Assure that an approximate solution can be made if certain approaches cannot be solved in the time provided.
- **Quarter 4.**
  - Write a technical paper on the three approaches.

Map Projections on Irregular Bodies- Background

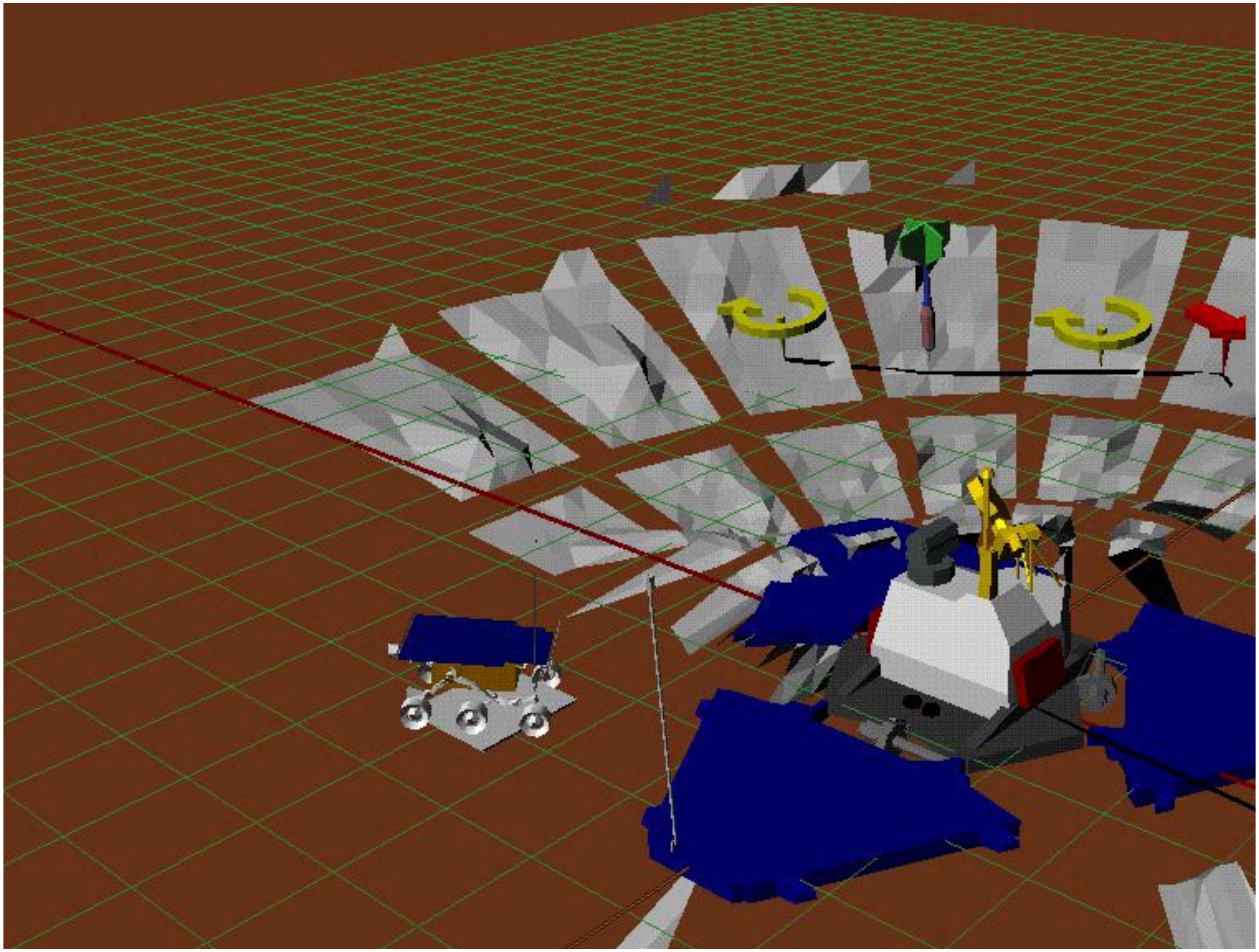
- **There are three approaches to this problem:**
  - **1. Projecting a triaxial ellipsoid.**
  - **2. Finding a numerical solution for the general case.**
  - **3. Solving the Cauchy equations by numerical integration.**
- **Past year progress:**
  - **Approach 1. The triaxial projection code has been written and is complete.**
  - **Approach 2. All the code has been written to implement a numerical approach for both authalic and conformal cases. Testing is now in process to match the results of approaches 1 and 2.**
  - **Approach 3. Dr Cheng's analytical approach has been successful in the authalic case. No solution has been found yet in the conformal case.**

FY98 Q1 Accomplishments and Follow-on Plans

Sense of Active Presence (SOAP)

- **Quarter 1: Accomplishments**
  - **Completed 3 1/50th scale models of the Pathfinder landing site using on-lab rapid prototyping facilities**
  - **Participated in Mars '01 rover navigation and ground system planning meeting with '01 rover team and others**
  - **Demonstrated SOAP software technology for creating immersive models for Sojourner navigation to Gale Squib and others of TMOD**
  - **Completed prototype GUI for rover operations**
- **Quarter 2: Planned**
  - **Generate models of baseline '01 rover configuration suitable for real-time display or VRML based interaction**
  - **Generate 3-dimensional icons for rover sequence items in a standard format**
- **Quarter 3: Planned**
  - **Integrate new capabilities into current RCW (Rover Control Workstation) system**
  - **Present paper, "Immersive Environments for Mission Operation: Beyond Mars Pathfinder" at SpaceOps '98**

Sense of Active Presence (SOAP)



Background

HDTV - Visualization and Analysis Testbed

- **Objectives: Complete the infusion of digital stereo HDTV technology into all components of mission planning and operations.**
  - **Add stereo HDTV Displays to SVT**
  - **Integrate HDTV recording capability into the Digital Image Animation Laboratory (DIAL)**
  - **Install digital video distribution system in MIPL**
  - **Install stereo HDTV projection system in MIPL**
  - **Demonstrate "Virtual Presence in Space" concept for NMP.**

FY98 Q1 Accomplishments and Follow-On Plans

High Definition Television Science Visualization Testbed (HDTV-SVT)

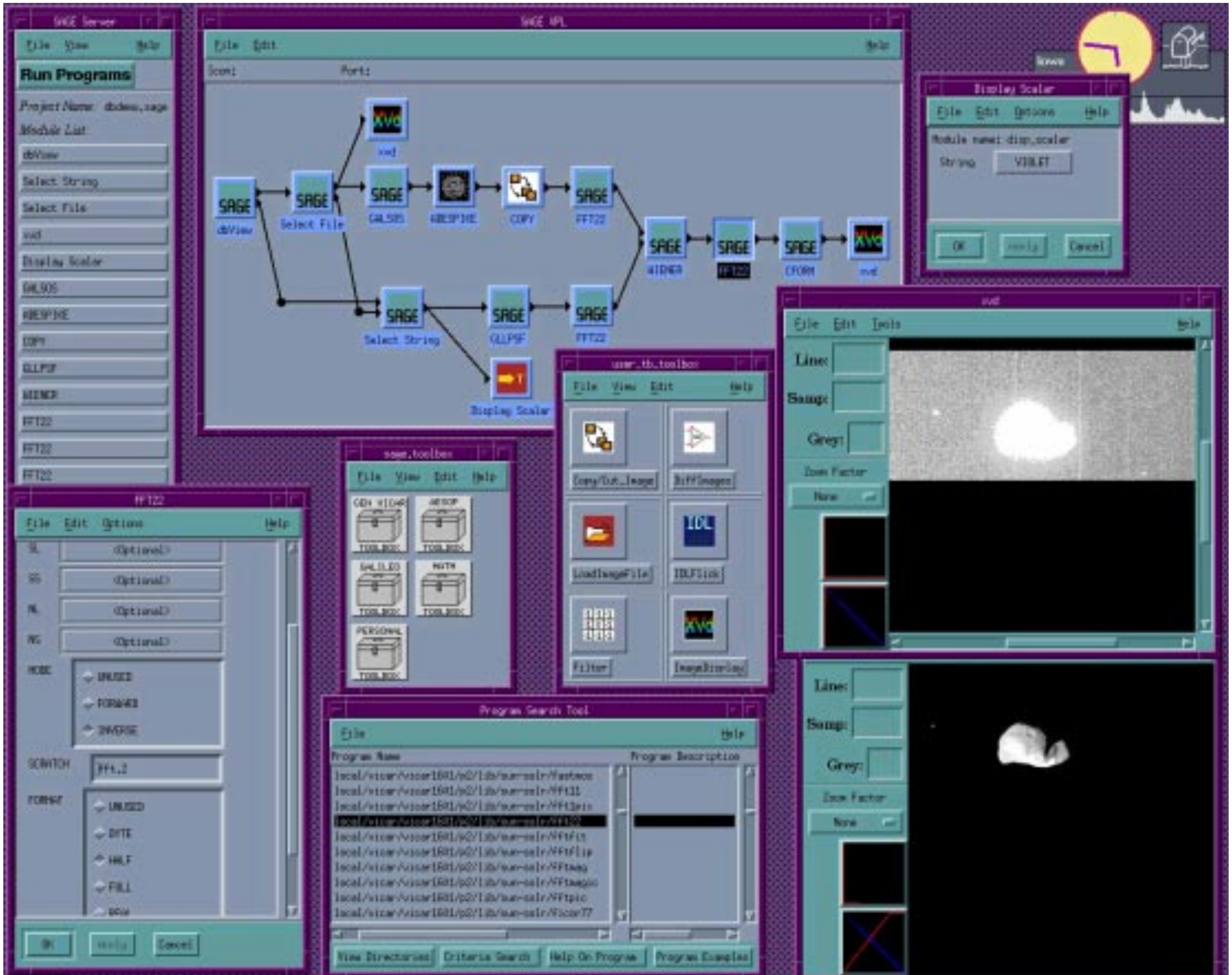
- **Quarter 1**
  - **Created Mars Pathfinder animations.**
  - **Created HDTV format science visualizations for NSCAT and the Topex/ Poseidon Projects**
  - **Installed HDTV digital serial/parallel converter.**
  - **Installed and tested W-VHS cassette HDTV Video Tape Recorder.**
  - **Demonstrated a variety of HDTV format science products to NASA HQ, flight projects, education institutions and the local community**
- **Quarter 2**
  - **Provide enhanced wide-band video switch for building 168- 4th floor.**
  - **Develop and install basic WEB control of video switching system**
- **Quarter 3/4**
  - **Add HDTV to MIPL user area station #8**
  - **Install basic wide-band video switching in building 301 Project Design Center (PDC)**

HDTV - Video Switching System

Web-Based HDTV- Video Switcher Control Panel

HDTV - Videro Switch Configuration Display

Background On SAGE



Multimission Application JAVA Interface Clients (MAJIC)

- **Quarter 1**
  - **Installed, and tested tools and compilers that are needed for the task. These include JDK, JFC, and Beans**
  - **Developed test programs that show how to use Java in the MAJIC context. These programs include socket connection between C++ server and Java client, Model-View-Controller architechture example, and an implementation of Command class that knows how to execute a user action, but has no functionality. The socket test program verified that Java socket classes can communicate with existing C++ socket mechanism.**
  - **Studied the Java Bean standard and decided that it will be extremely useful to implement display components as Java beans so that they will be easily reused by other programs (like Real-Time).**
  - **Studied the possibility of using Corba as alternative method to implement message passing. Result -- Java clients will implement socket mechanism, using a library called ACE.**
  - **Formed a working group to come up with the requirements for the upcoming Java VICAR image display program. Discussed and outlined some of the needed functionality and challenges posted by the current state of technology. For example, presenly Java doesn’t support partial file load, which will make it extremely hard to read large images.**
- **Quarter 2**
  - **Implement base classes.**

FY98 Q1 Accomplishments

Stereo Display Toolkit

- **Initiated transfer of stereo display hardware to developer's workstation to enable development of hardware-specific capability**
- **Investigated high-level design issues for the stereo display**
- **Began detailed design of anaglyph case**
  - **The fundamental issue is dealing with tiles that do not line up. The Image Widget is based on "tiles", or sections of the image, which are fetched from the data source (file) as a unit, and displayed as a unit. With independent plane pans, the tiles no longer line up. This is a particular problem when non-integer zooms are involved.**
  - **Several approaches for Image Widget modifications to support independent plane pans were identified and are being evaluated:**

FY98 Follow-on Plans

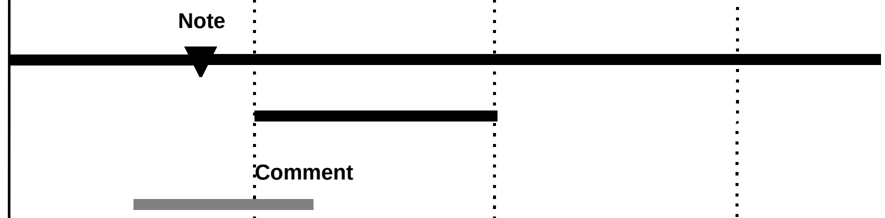
Stereo Display Tooklit

- **Plans Q2**
  - **Choose one of the approaches for Image Widget modifications, complete its design, and begin implementation.**
  - **Create "rapid prototypes" of StereoGraphics-type hardware support classes, to assist in designing the high-level API for the stereo display system.**
- **Plans for Q3/4**
  - **Complete implementation of display, both anaglyph and hardware.**
  - **Design, then implement, the stereo cursor capability.**
  - **Integrate capabilities into display application for end-user use.**

Advanced Science Processing and Visualization

Schedule

Task	FY98 Expanded			
	Q1	Q2	Q3	Q4
Major task description Subtask 1 Subtask 2 Next major task Slipped w.r.t. original FY98 plan				
Resources by FY ($K):	xxx			



N.B. Show expanded plan for FY98 and progress against plan for all identified work items. This information should come from your Annula Review schedule. Where re-planning has been required show this using a red broken line (as shown).